

E²ML

A VISUAL INSTRUCTIONAL DESIGN LANGUAGE

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Instructional Design from Craftsmanship To Production

The advent of technologies has changed our very idea of what a *course* is (Bates & Poole, 2003). Instructors in Higher Education are now daily supported by instructional designers or educational technology experts that provide advice for integrating Web-based activities, videoconference sessions, high-quality digital media presentations, etc. in their teaching activities. The process of designing courses has grown a more and more structured and interdisciplinary process (Szabo, 2002), one that is too complex for a lone-ranger professor to cope with (Bates, 1999). In some respects, teaching is thus developing from craftsmanship to a large scale production process (Cantoni & Di Blas, 2002), in which communication has become a critical variable.

A fairly recent research trend in the field of educational technology is the development of visual instructional design languages. This paper is a sort of tutorial aiming to introduce one of these new professional tools for designers: E²ML – Educational Environment Modeling Language.

In order to explain the relevance of E²ML, the first section is devoted to the identification of some features and issues concerning the Instructional Design process through the analysis of the literature. The second section introduces some relevant literature, among which the foundational work by Gibbons, and two other visual design languages. E²ML is presented in the third section through a detailed example, while additional references concerning other studies about the language are provided in section four. The conclusion presents a summary along with indications for further work.

Communication & Instructional Design

The daily work of the instructor and of the instructional designer in any tertiary educational organization is mostly interdisciplinary teamwork (Greer, 1991). The profiles in the team depend on the specific context even if, generally speaking, a team should involve “(...) any combination of subject experts or faculty, project manager, instructional designer, graphic designer, computer interface designer, desktop editor, Internet specialist, and media producer, depending on the design of the project” (Bates, 1999, p. 70; see also Achtemeier, Morris & Finnegan, 2003).

Each of these professionals makes use of a specific technical language, so that misunderstanding can easily endanger successful development. In fact, we cannot give for granted that a Literature professor with educational background understands the word “active learning” or “creative discussion” in the same way as a Web programmer does. Nevertheless, the person in charge of creating the artifacts that should foster the learning activity is the latter. The quality of the educational experience heavily depends on the communication between the two. Such a scenario grows more complex when eLearning programs require collaboration between different institutions or organizations. These problems clearly call for the definition of a *lingua franca* among the different profiles involved in instructional design.

Other issues are at stake too. How can the final learning activity maintain its overall consistency? How to seamlessly merge the contributions of all profiles into one final “product”? The overall complexity of the design of instruction can be managed by assigning specific tasks to several specialists and by organizing the production process into phases, following a project management approach (Bates, 1999; Greer, 1992). Several models of Instructional Design have been proposed describing the main phases a well-structured project should undergo, summarized by the basic steps of the ADDIE model, which reflects much of the practice as designers describe it (Rosenberg, Coscarelli & Hutchinson, 1999): Analyze, Design, Develop, Implement, and Evaluate.

All authors stress the role that communication plays in the organization and management of the development process (cf. Dick & Carey, 1996; Smith & Ragan 1999; Morrison, Kemp & Ross, 2002). Cox & Osguthorpe (2003) argue that management activities cover about half the time of the instructional designer's activity.

The management of the design and development process is based on what Greer (1992) and Bates (1999) call a blueprint - usually a written text in natural language. Is there a way to produce a more standard and synthetic description of the instruction? In particular all Instructional Design models include the evaluation and revision phases *at the end* of the design process (e.g. Dick & Carey, 1996), and some of them suggest a constant tryout and revision process (e.g. Greer, 1992). While a thorough control of quality is necessary, both solutions are costly, as they take place after the production has started, even if in some cases they only involve prototypes. Is it possible to support at least a partial quality check at design time?

Finally, after a course has been developed, usually the only documentation available are the actual learning materials. This raises some issues in the case a redesign or adaptation process is required for reuse, especially in the case the original designer is not available. Is it possible to produce a documentation that can guide the reuse and adaptation of the instruction?

A Language For Instructional Designers

In a recently published article, Waters & Gibbons (2004) provide an interesting approach to instructional design communication. Drawing examples from Dance, Chemic and Architecture, the two authors point out that almost any creative and technological field has developed one or more notation systems and design languages. According to their definitions, (a) a *design language* is a personal and abstract set of concepts that a designer can use for creating design structures; while (b) a *notation system* is a tool for providing imperfect but visible and public expression to design structures. In other words, an architect creates a new and original building thanks to a set of aesthetical, compositional and technical concepts, and than expresses her ideas through a set of drawings that allow her to share the project with other people.

As Waters and Gibbons emphasize, there is a tight relationship between design languages and notation systems, as between our thought and our mother tongue. "As designers improve and extend their personal design languages, this in turn calls for extensions and improvements to the notation system. The notation system then is capable of expressing more interesting and complex designs and easily leads to innovation." (Waters & Gibbons, 2004; p. 59). This looping relationship is summarized in Figure 1.

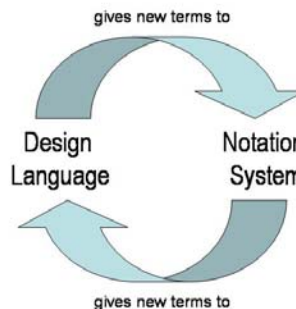


Figure 1 – Cycle of improvement (taken from Waters & Gibbons, 2004, p. 59)

Coming to the field of Instructional Technology, the authors report that instructional designers use idiosyncratic and "personal" design languages and notation systems, while no complete blueprint language exists. The work of Horn (1974) and Merrill (1983) represent a step toward the development of a language, but their contributions mainly focus on a particular layer of a design – namely Horn on content structures, and Merrill on strategy structures. Eckel (1993) has also proposed an instructional language centered on interaction design.

Gibbons & Brewer (2004) identify at least three benefits that ID would get from a shared notation system: (a) remembering designs; (b) having a virtual problem-solving workspace, for trying out new solutions; and (c) having a lab for sharpening concepts and merging them. To these I add the improvements of a shared language for discussion, through which different design traditions and schools could meet.

The literature research conducted during the development of E²ML also revealed the lack of a visual design language for Instructional Design. Morimoto (2003), working on notation systems for lesson plans, also reports the lacking of such a design tool.

Recently, the introduction of Learning Technology standards has brought to the developments of languages that could serve as an interface between the humanistic world of instructors and the technical one of IMS and SCORM. The works by Lischka (see e.g. Lischka & Karagiannis, 2004; Bajnai & Lischka, 2004) with eduWeaver and Derntl with the Person-Centered e-Learning patterns (Derntl & Mangler, 2004; Derntl & Motschnig-Pitrik, 2004) are a positive advancement in such direction.

E²ML Language Definition

E²ML – Educational Environment Modelling Language is a visual language for instructional design. Its general approach is visualization, and it is targeted to instructors and instructional designers.

The main issue E²ML is concerned with corresponds to what Greer (1992) and Reigeluth (1983) called the development of a blueprint: a representation of the instruction that all stakeholders, designers, developers and instructors can see, understand in a similar way and, hopefully, agree upon. According to the categories proposed by Gibbons & Brewer (2004), E²ML is a design language with a very limited number of basic concepts, coupled with a visual notation system.

This section introduces the language through the example of a two-day intensive course in Effective Mediated Communication (EMC) delivered by the author to 20 commercial managers from an international private Swiss-based healthcare firm in 2004.

Document Sets

An E²ML blueprint consists of three sets of documents. Each of them provides support for specific design tasks. The three sets are:

1. Goal Definition, i.e., a declaration of the educational goals. This is composed by two documents: the goal statement and the goal mapping.
2. Action Diagrams, i.e., the description of the single learning and support activities designed for the instruction.
3. Overview Diagrams, i.e., two different overviews of the whole design, the dependencies diagram and the activity flow.

The documents are described in the following sub-sections in their standard form. As any real design process and any real instructional situation have their own unique features, they can be adapted (simplified or detailed) to the needs of the specific context or design team. They are produced at different moments in the design process, and do not have a tight correspondence with specific phases. The order of presentation in this paper, which does not follow the numbering of document sets, was selected for its suitability to the case study, and should not be understood as an indication of method. The elements of E²ML can be implemented flexibly, in a sequence tailored to the needs of each project.

Goal Definition (Document Set 1)

Expressing learning goals means creating a compass for design, and is important for different reasons: selecting what to teach, how to teach it, what to evaluate and how to make the whole instruction consistent (Anderson & Krathwohl, 2001; Gronlund, 1995; Yelon, 1991). The most widely known models for learning goals (or instructional objectives) are those by Bloom (1956; 1964), Gagné, Briggs & Wager (1992) and Merrill (1983).

One central issue for the development of relevant and consistent goals is collaboration with Subject-Matter Experts (SME) and negotiation with stakeholders. A second issue is creating a common understanding in the whole team about the goals as primary requirements for the project. The first E²ML document set aims to provide a support for these two communication processes.

Goal Statement Table. The goal statement describes learning goals (possibly sub-goals and objectives) according to an extensible set of parameters, the core being an identifier tag, the goal statement, the target, the main stakeholders, the instructional approach and an importance score. The list can be extended according to the needs of each project. The EMC course had the following goals (Table 1):

GOAL STATEMENT					
TAG	STATEMENT	TARGET	STAKEHOLDER	APPROACH	IMPORTANCE
A1	Recognize critical success factors in communication	All	Head	Case studies and discussion	5
A2	Analyze successful and unsuccessful communications	All	Head		4
A3	Recognize differences between direct and mediated communication settings	All	Head		5
B1	Recall key concepts of communication	All	Head	Critical discussion on movie clips	4
C1	Perform effective videoconferencing	All	Head	Guidelines, examples and exercises	2
C2	Perform effective audioconferencing	All	Head		3
C3	Write effective emails	All	Head + Mktg. Director		5
C4	Deliver effective presentations	All	Head + Mktg. Director		5
C5	Effectively integrate corporate Web sites into communication	All	Mktg. Director		3

Table 1. Goal statement for EMC

The goal statement table is an orderly summary of the goals of the instruction. Yet often the verbal expression of goals can be ambiguous or unclear, especially in a multidisciplinary environment. For this reason the goal mapping, presented below, can be a powerful complement in the goal definition process.

Goal Mapping. In order to enhance communication, learning goals can be visually expressed by mapping them on a visual grid or representation, such as Merrill's Content-Performance Matrix (1983), the revised Bloom's taxonomy (Anderson & Krathwohl, 2001), or the QUAIL model (Botturi, 2003 a; Botturi, 2004 a). According to Anderson & Krathwohl (2001), trying to classify a goal lets all implicit understandings emerge, and is a chance to align the whole team. Two points deserve great care: first of all, the representation device should be consistent with the kind of goals addressed (cognitive, psychomotor, affective, etc...); secondly, the designer should be familiar with the representation and be conscious (if not share) its underlying implications for learning. This is why E²ML simply suggests the use of visuals, leaving the choice to the designer.

The goals for the EMC course are visualized in Figure 2 using the Quail model.

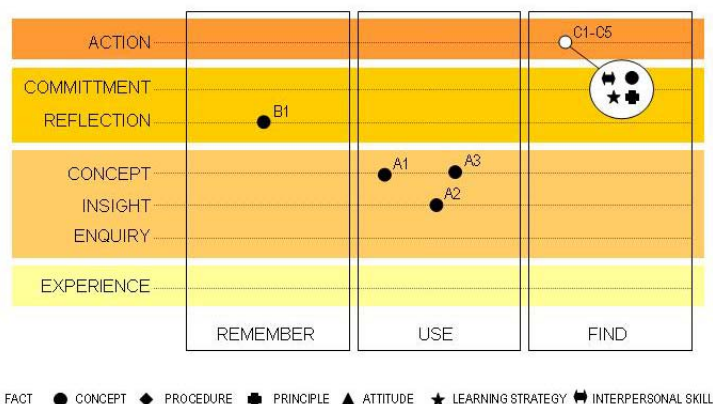


Figure 2. Goal visualization for the EMC course with the QUAIL model

Document set 3 contains diagrams that provide “the big picture”, a synthetic view of the whole instruction. They are probably the most interesting for practitioners. Overview diagrams serve as reference for planning the development process and as organizers of other documents and project deliverables, and are a powerful communication tool both for intra-team communication and for negotiation with clients and external partners. These diagrams are conceived for a continuous development throughout the design process, thus becoming a sort of interactive shared map of the instruction.

Dependencies Diagram. Each educational environment has a deep structure that connects its activities and creates one meaningful whole. These relationships are not necessarily mimicked in the streamlined disposition of the activities on the schedule.

Activities (or *actions* – a definition is provided below) are represented by boxes. The relationships supported by E²ML are: (a) Learning prerequisite: the first action provides a learning outcome that is the prerequisite for the second action (e.g., a lecture provides concepts for the following analysis work); (b) Product: the first action produces some artefact that is required as input for the second action (e.g., a group-work activity produces a presentation which is shown during the following class discussion). Product arrows may be tagged with an indicator of the product (e.g., report); and (c) Aggregation: an activity is part of another activity (it is a sub-activity). For improving legibility, actions can be grouped into *trails*, or logical groups of actions, e.g., all lectures, or all the actions that form a specific activity in a course, etc.

The EMC course includes three main groups of activities (grouped with trails): some introductory lectures, in-depth practice-oriented sessions about specific media, and exercises. Before the course, participants are asked to critically scan the last emails they received and to identify the “most and least communicative ones”, trying to figure out why. The resulting diagram, which actually contains more information about specific dependencies, is represented in Figure 3. Dot-end arrows are learning pre-requirements, while simple arrows are product relationships (no aggregations are shown in this case).

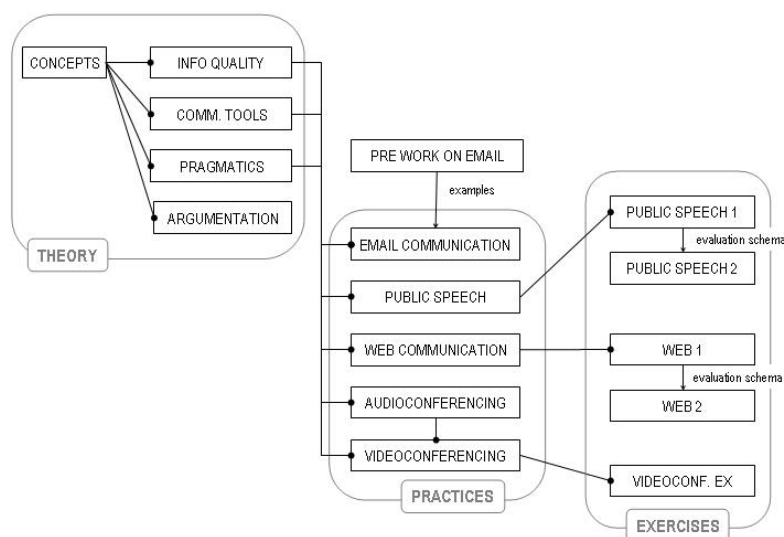


Figure 3. EMC course dependencies diagram.

During design and development, the dependencies diagram can be useful to identify cross-unit connections, and to provide developers with an idea of the “big picture” that the instructor has in mind. Moreover, imagine that during the course a session has a poor outcome for contingent reasons (e.g. a technical failure in the AV equipment): the dependencies diagram provides a support to identify (a) possible waterfall effects on other activities, and (b) potential activities in which to propose a remedy.

Activity Flow. The activity flow is a visualization of the instruction calendar and provides an overview of educational activities during the course time span. It is similar to a flowchart diagram that represents each learner’s path through the instruction. Actions are sequenced or ordered into more parallel branches. Each action can take place at a defined moment in time (e.g., on a particular date/time) or be allocated for free execution within a defined

timeframe. Splits (branches) can be added to the action flow as advanced elements, indicating conditions, options, multiple selections, parallel activities or non-sequenced actions (or *any-order actions*, i.e., branches in the activity path where a number of activities should be completed in any order).

The EMC course activity flow (Figure 4) exploits an hourly grid, and includes the same activities displayed in the dependencies diagram plus two introductions and two course evaluation discussions – they were not included in the dependencies diagram as they do not have tight connections with other activities. While the dependencies diagram was built following the inner relationships of the subject matter, the flow shows some adaptation to time constraints and a distribution of workload along with a continuous change in the type of activity. The ARGUMENTATION theory part for instance, which is not a pre-requirement for any other activity, was placed in a different moment than the other theory parts, which are grouped in Day 1.

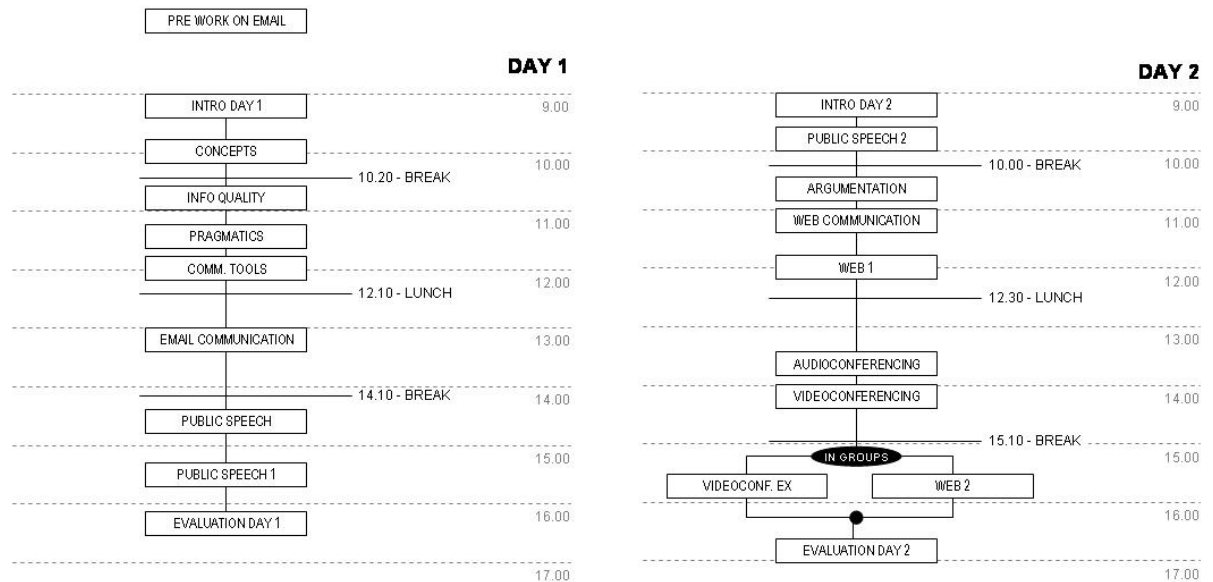


Figure 4. EMC course activity flow

The Activity flow can help to keep track of the chronological sequence of activities and to manage complex situations with structured group work or multiple student options.

Action Diagrams (Document Set 2)

As already mentioned, E²ML only includes a very limited set of design concepts. The main one is that of *action*: a learning environment is a context in which events happen (cfr. Gagné, Briggs & Wager, 1992).

For E²ML the *action* is the performance of a set of acts with a unity of purpose by defined acting subjects. Unity of purpose means that the action is aiming at one thing, e.g., producing a report, completing an exercise, achieving the understanding of a concept, etc. The acting subjects can be a single learner along with the tutor, a whole class with the instructor, a tutor alone, etc. An action can be split in several sub-actions according to the time and/or space unity criterion in the specific setting (a single lecture or a videoconference). This second distinction (time/space) should of course match with the previous one (goal/subject).

The general schema for the representation of an action is presented in Figure 5. The upper part of the diagram contains the proper identification for the action, i.e., its identifier tag, name, type (learning or support) and the involved roles (the acting subject). The middle-left area describes the initial state, i.e., the necessary and sufficient conditions for learning to be achieved, or for the performance to be successfully completed. The middle-right area describes the (desired) final state after the action performance. Finally, the lower part of the diagram contains a description of the action performance, including locations and tools. The squares hanging on the right-

hand side are references to the learning goals as defined in the goal statement, thus providing a tight connection between goals and activities. For a detailed description of all fields please refer to (Botturi, 2003 b)

ACTION NAME		TAG
ROLES		TYPE
PREREQUIREMENTS	EXPECTED OUTCOMES	Gx
PRECONDITIONS	SIDE-EFFECTS	Gy
INPUT	OUTPUT	
PROCEDURES + DURATION		
LOCATIONS		
TOOLS		

Figure5. Action diagram schema

As an example, Figure 6 shows the first activity in the EMC flow – namely the *email observation pre-work*.

PRE WORK ON EMAIL		PRE WORK
All participants individually		LEARNING
[no pre-requirements]	Develop a critical attitude toward daily email communication.	A1
	Arise some questions about the meaning of <i>effective</i>	A2
		C3
Daily email use	[no side-effect]	
Invitation to do the job by the head	Good and bad emails with short explanations (to be sent to the instructor)	
Personal work: one week prior to the course, each participant is asked by the head to do this activity. They should take 10 minutes every day to review their email exchanges and to select the best and worst emails they wrote and received. They then write a summary, including the email bodies and send it to the instructor.		
Anywhere		
[no support]		

Figure 6. Email pre-work in the EMC course

Action diagrams provide a synthetic yet detailed description of the very bricks of the instruction: teaching and learning activities. Although time-consuming in production, these diagrams can be taken as a complete documentation of the instruction for archival and reuse. Once more E²ML supports the description of the instruction, and does not directly provide design methods. By doing this, it offers tools for not overlooking details, such as locations or tools required for some activity, and for seeing the project in a structured and synthetic way.

Who Uses E²ML?

E²ML was developed for instructional designers, and every effort was made in order to make it usable, understandable and practical to them. In the same way they develop their own jargon – specifying terms as *template* or *blueprint*, or creating expressions as *round disclosure* - designers should also feel free to take E²ML or any of its parts, and extend it, adapt it and make it suitable to their problems. E²ML can be also used only partially, without exploiting all its features or using them only for some activities.

Novice designers could use E²ML as a language for practicing design. From this perspective, having a language means having a possibility to focus on design itself without slipping away to development – which is particularly easy if learning materials are the only tangible product of the whole process.

Should or could E²ML visualizations be used with students? E²ML diagrams are not conceived for them in the same way technical blueprints for a two-floor house are not the best support for letting the senior couple that

bought it dream about their retirement. Nevertheless, a visualization of the flow of specific activities is proved to enhance student performance in particular settings, such as problem-based learning (Santoro, Borges & Santos, 2003). Diagrams could also be used for negotiating some steps in the instruction, and to improve the critical comprehension of the learning process. In order to make them more effective, the style of diagrams should be rearranged and made more appealing.

Although the analysis of a single case might not have made it clear enough, E²ML does not have a unique access point, and does not impose to start e.g. from goals. It is a language, and as such it can be used with different strategies that could be taken from other Instructional Design models.

Other References For E²ML

A more detailed introduction to E²ML can be found in (Botturi, 2003 a). Other publications (Belfer & Botturi, 2004; Belfer & Botturi, 2003) explore the use of the language for the definition of pedagogical patterns, i.e. reusable gist of solutions to recurrent instructional problems. The complete description of the language, along with a critical comparison to other ID models and with learning technologies standards can be found in (Botturi, 2003 b).

A first evaluation of the perception of usefulness of E²ML is reported in (Botturi, 2004 b): its results clearly indicate that instructional designers see a visual language as a potentially useful tool for their practice, given that it is simple, flexible and with a plain learning curve. According to their perception, E²ML is mostly useful for keeping the overall consistency of a course, and in particular to discuss the consistency of goals and instructional activities with the instructors or course authors, as “they usually discuss the goals and then forget them in the actual planning”. Designers also think that E²ML is useful to blueprint a course, as it “works well in organizing people's thinking”, and “may speed up collaboration”, also allowing a greater detail than textual blueprints. Finally, it helps to “make the evaluation more evident”, identifying activities in which the achievement of specific goals is assessed.

Conclusions

The challenges of the last decades to Higher Education brought to a shift in the idea of course, which resulted into a more complex professional environment for instructional designers. This is particularly true from the point of view of communication: a design team is by nature interdisciplinary and in interaction with stakeholders, external partners and other design teams. E²ML was conceived as a visual language that can smoothen and enhance project communication. The structure of the language, articulated in three document sets, was presented through one example. Its main idea is modelling the instruction as a set of interrelated actions, aimed at goals and performed by actors with specific roles.

The references provided can bring further information and research reports on this language to the most interested readers. As a practitioner, I still think that the best way to learn a language and to assess the benefits of a tool is trying it out hands-on, playing around a little bit and integrating it in my personal way of designing while sharing it with colleagues, thus creating a mutual understanding.

The main assumption behind E²ML is that a special visual language may enhance communication, and enhanced communication may improve design; improved design may increase the quality of educational programs. In Italy, where I come from, five centuries ago, travelers to the New World brought back a new vegetable, before unknown in Europe: the tomato (actually, the first ones that arrived in Europe were golden, and not red, and we still call them *pomodoro* - golden fruit). That novelty, in the hand of experienced and creative cooks, contributed to the growth of our culinary tradition, which is now famous all over the world with *pasta* and *pizza* (actually, we do have much more than that!). I hope that this language, in the hand of experienced and creative designers, might contribute to enhance the quality of education and learning.

References

- Achtemeier, S.D., Morris, L.V. & Finnegan, C.L. (2003). Considerations for Developing Evaluations of Online Courses. *Journal of Asynchronous Learning Networks*, 7(1). Retrieved September 2004, 15th from http://www.aln.org/publications/jaln/v7n1/v7n1_achtemeier.asp
- Anderson, L.W. & Krathwohl, D.R. (2001). *A Taxonomy for Learning, Teaching and Assessing. A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Addison Wesley Longman

- Bates, T.W. & Poole, G. (2003). *Effective Teaching with Technologies in Higher Education*. San Francisco, CA: Jossey-Bass
- Bates, T.W. (1999). *Managing Technological Change*. San Francisco, CA: Jossey-Bass
- Bajnai, J. & Lischka, J. (2004). Planning and Simulation in an E-Learning Engineering Framework. *EDMEDIA 2004*, Lugano, Switzerland
- Belfer, K. & Botturi, L. (2004). Online Learning Design with Pedagogical Patterns. *SALT Orlando Conference 2004*, Orlando, Florida
- Belfer, K. & Botturi, L. (2003). Pedagogical Patterns for Online Learning. *ELEARN 2003*, Phoenix, Arizona
- Bloom B.S., Krathwohl, D.R. et Al. (1964). *Taxonomy of Educational Objectives: The Classification of Educational Goals, by a committee of college and university examiners. Handbook II: Affective Domain*. New York: Longmans, Green & Co.
- Bloom B.S., Krathwohl, D.R. et Al. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals, by a committee of college and university examiners. Handbook I: Cognitive Domain*. New York: Longmans, Green & Co.
- Botturi, L. (2004 a). Visualizing Learning Goals with the Quail Model. *Australasian Journal of Educational Technologies - AJET 20(2)*, 248-273
- Botturi, L. (2004 b). A Visual Languages for Instructional Design: Evaluating the Perceived Potential of E2ML. *EDMEDIA 2004*, Lugano, Switzerland
- Botturi, L. (2003 a). E2ML - A Modeling Language for Technology-dependent Educational Environments. *EDMEDIA 2003*, Honolulu, Hawaii
- Botturi, L. (2003 b). E2ML – Educational Environment Modeling Language. Ph.D. Thesis. Retrieved September 2004, 15th from <http://www.istituti.usilu.net/botturil/web/e2ml/index.htm>
- Cantoni, L. & Di Blas, N. (2002). *Teoria e Pratiche della Comunicazione*. Milano: Apogeo
- Cox, S. & Osguthorpe, R.T. (2003). How do Instructional Designers Spend their Time? *Tech Trends 47(3)*, 45-47
- Derntl, M. & Mangler, J. (2004). Web Services for Blended Learning Patterns. *IEEE International Conference on Advanced Learning Technologies*, Joensuu, Finland
- Derntl, M. & Motschnig-Pitrik, R. (2004). Patterns for Blended, Person-Centered Learning: Strategy, Concepts, Experiences, and Evaluation. *ACM Symposium on Applied Computing (SAC04)*, Nicosia, Cyprus
- Dick, W. & Carey, L. (1996). *The Systematic Design of Instruction* (4th ed.), New York: Harper Collins College Publishers
- Eckel, K. (1993). *Instruction Language: Foundations of a Strict Science of Instruction*. Englewood Cliffs, NJ: Educational Technology Publications.
- Gagné, R.M., Briggs, R. & Wager, W. (1992, 4th ed.). *Principles of Instructional Design*. Fort Worth, TX: Harcourt Brace Jovanovich College Publishers
- Gibbons, A.S. & Brewer, E. (2004). *Elementary Principles of Design Languages and Design Notation Systems for Instructional Design*. To be published in Spector, M. & Wiley, D. *Innovations to Instructional Technology: Essays in Honor of M. David Merrill*. NJ: Lawrence Erlbaum.
- Greer, M. (1992). *ID Project Management: Tools and Techniques for Instructional Designers and Developers*. Englewood Cliffs, NJ: Educational Technology
- Greer, M. (1991). Organizing and Managing the Instructional Design Process. In L.J. Briggs, K.L. Gustafson & M.H. Tillman (Eds.), *Instructional Design: Principles and Applications* (2nd edition, pp. 315-343). Englewood Cliffs, NJ: Educational Technology
- Gronlund, N.E. (1995, 5th ed.). *How to Write and Use Instructional Objectives*. Englewood Cliffs, NJ: Prentice Hall
- Horn, R.E. (1974). Information mapping. *Training in Business and Industry*, 11(3)
- Lischka, J. & Karagiannis, D. (2004). Modeling and Execution of E-Learning Resources, *ACM Symposium on Applied Computing (SAC04)*, Nicosia, Cyprus
- Merrill, M.D. (1983). Component Display Theory. In C.M. Reigeluth (Ed.), *Instructional Design Theories and Models: An Overview of Their Current Status* (Vol. 1, pp. 279-333). NJ: Lawrence Erlbaum Associates
- Morimoto, Y., Kogure, T., Kouno, S., Yokoyama, S., Miyadera, Y. (2003). A Meta-Language for a Teaching-Plan-Making Support System. *EDMEDIA 03*, Honolulu, Hawaii
- Morrison, G.R., Ross, S.M. & Kemp, J.E. (2003). *Designing Effective Instruction* (4th edition). New York: Wiley & Sons
- Reigeluth, C.M. (1983). *Instructional-design Theories and Models: An Overview of Their Current Status*. New Jersey: Lawrence Erlbaum Associates Publishers

- Rosenberg, M. J., Coscarelli, W.C., & Hutchison, C.S. (1999). The Origins and Evolution of the Field. In H. D. Stolovitch & E.J. Keeps (Ed.), *Handbook of Human Performance Technology* (2nd edition, pp. 24-46). San Francisco: Jossey-Bass
- Santoro, F.M., Borges, M.R.S. & Santos, N. (2003). Using Workflow Concepts to Support Collaborative Project-based learning. *EDMEDIA 2003*, Honolulu, Hawaii
- Smith, P.L. & Ragan, T.J. (1999). *Instructional Design*. New York: Wiley & Sons
- Szabo, M. (2002). Competencies for Educators. In Adelsberger, H.H., Collis, B. & Pawlowsky, J.M. (eds.) *Handbook on Information Technologies for Education and Training* (pp. 381-397). Berlin: Springer
- Waters, S. & Gibbons, A.S. (2004). Design Languages, Notation Systems, and Instructional Technology: A Case Study. *Educational Technology Research & Development*, 52(2), 57-68
- Yelon, S.L. (1991). Writing and Using Instructional Objectives. In L.J. Briggs, K.L. Gustafson, & M.H. Tillman (Eds.), *Instructional Design: Principles and Applications* (2nd edition, pp. 75-121). Englewood Cliffs, NJ: Educational Technology